A Systematic Approach to Marine Debris Reduction Efforts and Education in New Hampshire

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***Abstract*- A recent focus of marine debris research is to identify and target pollution sources so that solutions to the problem can be developed through policy and education. This project hopes to expand upon this focus by also examining public attitudes toward marine debris and using this information with cleanup data to systematically implement and test community mitigation techniques. One objective of this research was to examine current community marine debris cleanup and reduction efforts in New Hampshire (as a baseline) by analyzing beach cleanup data. Marine debris monitoring data has been collected by the Blue Ocean Society for Marine Conservation over the past four years. Cleanups have been conducted by the organization at fourteen different New Hampshire sites during this time. A data summary was composed for each which included a compilation of data from 2002 through 2006. Additionally, marine debris composition (e.g., land-based, ocean-based, etc.) was mapped in Geographic Information Systems (GIS) along with significant influencing factors. Besides mapping the marine debris quantity and composition per collection site, the powerful component to GIS is that any potential influencing data available can be tied to all of these locations. The full integration of all available data will allow the evaluation of trends and correlations in marine debris data with myriad potential influences. Additionally, because the amount of ocean-based debris found on the NH Seacoast is greater than land-based debris for the majority of beaches, a new outreach program targeting commercial and recreation fisherman is being implemented. Finally, new technologies for monitoring, specifically, using personal digital assistants (PDAs) with integrated GPS systems to collect marine debris or oiled shoreline data have been evaluated. This technology could be transferred to other applications for monitoring marine pollution.**

I. Introduction

Monitoring marine debris accumulation began soon after it was recognized as a major pollution issue. Marine debris continues to be implicated as a continued to threat to marine environments and coastal communities [1]. There are several ways of assessing marine debris issues. This research conducts beach surveys and examines the types and quantity of solid waste that accumulates onshore. Marine debris is not only aesthetically unpleasing as litter on beaches and shorelines, it may also cause harm to human health and the environment. The most widely known damage from marine debris is increased mortality of wildlife from entanglement or ingestion. At least 267 marine species have been affected by both entanglement and ingestion of marine debris including six of the seven species of sea turtles in the world, 44% of seabirds and 43% of marine mammals [2-6]. Stomach contents of the Northern Fulmar were studied finding that they ingest almost any object floating on the sea surface including plastic debris [7]. A study was conducted in Southern Brazil which concluded that 13.2% of a local species, green turtles, died due to ingestion of anthropogenic debris (mostly plastic bags) [8]. The health and safety of beachgoers may also be affected by debris containing sharp glass, metal, or plastic.

Marine debris also presents hazards to fishing and industrial systems by fouling boat propellers, clogging water intakes or blocking pumping systems. Lost fishing equipment (e.g., nets and traps) can "ghost fish," or float in the ocean and continue to catch fish and kill wildlife. This can have an impact on the fishing and shellfish industry [9-10]. Tourism can also be affected by marine debris and other litter. In the 1980's, when large amounts of waste were found on coastlines (e.g. medical waste in New York), many communities lost millions of dollars from a drop-off in tourism, and increased beach cleanup maintenance [11]. The success of beach tourism is an essential economic component to many communities, states and countries, including New Hampshire.

A recent focus of marine debris research is to identify and target pollution sources so that solutions to the problem can be developed through policy and education. Through a joint partnership among academia, the University of New Hampshire (UNH); a community-based non-profit, Blue Ocean Society for Marine conservation (BOS); and a federal agency, the National Oceanic and Atmospheric Association (NOAA), this research hopes to expand upon this focus by also examining marine debris beach cleanup data to systematically implement and test community mitigation techniques. Specifically, this paper discusses examining current community marine debris cleanup and reduction efforts in New Hampshire (as a baseline) by analyzing beach cleanup data, developing new forms of data collection including the use of personal digital assistants (PDAs), and utilizing geographic information systems (GIS) mapping to analyze marine debris data collected from New Hampshire beaches.

II. Beach Data Summaries

Blue Ocean Society for Marine Conservation was incorporated as a non-profit organization in January 2001, and staff at the organization started participating in local marine debris monitoring the following spring (May 2001). BOS' marine debris

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monitoring program started with cleanups at Jenness Beach in Rye, NH, in which BOS started recruiting community volunteers to participate. While Jenness Beach is cleaned each month, BOS also expanded monitoring and cleanup to other local beaches, with an Adopt-a-Beach program (businesses, schools and clubs clean other NH coastal sites monthly). Through 2006, the program had fourteen cleanup/monitoring sites in NH (Table 1) and now currently serves seventeen beaches. BOS staff members also present educational programs across New Hampshire and nearby areas to educate students about the marine environment and inspire positive behavioral change. In 2005, BOS shared all of its historical data with UNH for further analysis to jointly develop a systematic approach to marine debris reduction in New Hampshire.

Table 1. List of Beaches with Marine Debris Identification and Removal by Blue Ocean Society Volunteers (2002-2006)

Site	**Location**
Jenness Beach	Rye
New Castle Common	New Castle
Wallis Sands	Rye
North Beach	Rye
Plaice Cove	Hampton
Sawyer's Beach	Rye
Peirce Island	Portsmouth
Odiorne Point Beach	Rye
Seabrook Beach (2 Sections)	Seabrook
Hampton Beach (5 Sections)	Hampton
Flounder Cove	Hampton
Bass Beach	N.Hampton
Foss Beach (2 Sections)	Rye
South Mill Pond	Portsmouth

Monitoring and cleanups are conducted in cooperation with and with permission from state and local entities. Two of the beaches monitored in NH (Jenness Beach and Plaice Cove) are also included in the scientifically designed U.S. EPA's National Marine Debris Monitoring Program (NMDMP). At each cleanup, volunteers track debris items of interest by marking on BOS-provided data cards. Currently, data are stored and entered into a Microsoft Excel spreadsheet. The interpretation of marine debris data results collected during BOS events should be viewed with a qualification: although volunteers are told that the data collected is for a scientific study, during a beach cleanup, a volunteer's main concern is often picking up litter and debris, not necessarily recording the data accurately. Also, the locations for beach cleanups are not all randomly selected (only the NMDMP sites were); however, in this case, over 25% of the NH coastline is being monitored for marine debris. Although the protocol is standardized through the data card with direction from BOS, it is collected by volunteers and the only quality assurance and control measures is a review of the data by BOS and UNH personnel. Even so, marine debris data collected in this manner is often the only way such extensive data can be compiled. Additionally, the large quantity of beach cleanup work completed and data collected provides a good indication of the magnitude and nature of marine debris in New Hampshire.

BOS, like the Ocean Conservancy that performs the International Coastal Cleanup each year, has categorized marine debris into three generalized sources: land-based, ocean/waterway-based, and general sources. Land-based sources are primarily related to littering, recreation and beach users. Ocean/Waterway-based sources of debris include littering (from piers/docks/boats), recreational boating, recreational fishing (from piers/docks/boats), commercial fishing, merchant vessels, military/research vessels, and offshore oil/gas platforms. Other items are classified as general source items because they cannot be traced to a specific activity or sole source. The types of debris in each source are outlined in Table 2.

Table 2. sources of Marine Debris Items Identified and Removed by blue Ocean Society Volunteers in New Hampshire

Land		Ocean		General
Cigarette butts	Cotton swabs	Rope > 1m	Salt bags	Metal beverage cans
Straws	Oil/gas containers	Fishing line	Pipe-thread protectors	Plastic bottles-beverage
Balloons	Syringes	Nets > 5 meshes	Lightbulbs/tubes	Plastic bags less than 1m
Styrofoam cups		Traps/pots	Light sticks	Beverage bottles (glass)
Tampon applicators		Gloves	Cruiseline logo items	Plastic bottles-other
Condoms		Straps-open	Straps-closed	Plastic bottles-food
Six-pack rings		Plastic sheets	Fish baskets	Plastic bags > 1m
		Floats/buoys		Plastic bottles-bleach/cleaner

Data collection during cleanups is important for analyzing trends and evaluating education and outreach efforts. As a part of this project, the data for each beach was examined over time. A data summary was composed for each beach which included a compilation of data from 2002 through 2006. To examine specific debris item trending over time, debris collected was normalized on a per person basis (adults and children are recorded differently: adults were counted as one person and children are counted as 0.5 person). As an example of a beach summary, Jenness Beach (the beach which has been monitored the longest) data are presented here. Jenness Beach represents a typical beach monitored along the New Hampshire Seacoast at 0.5 km (1/3 mile) (Figure 1). Through 2006, debris has been identified and removed from the beach on 118 occasions for a total collection of 2,711 kg (5,966 lb). A total of 1,864 people have volunteered in clean-ups, with an average of 7-10 people participating in each event.

The percentage of the sources of items (minus cigarette butts), is shown in Figure 1. As will be shown later, cigarette butts (a land-based item) are the most frequent item encountered; however, since the number collected is so large, they heavily skew the source percentages. If cigarettes were included in the pie chart shown in Figure 1, the land-based percentage would be 71%, ocean-based 18% and general 11%. With the exclusion, the graphs shows that other than cigarette butts, ocean-based debris is potentially a significant source. The frequency of items found on Jenness Beach was assessed. The most frequent debris items collected for Jenness Beach cleanup data from 2002 through 2006 are cigarette butts, rope greater than 1 m, straws, balloons and metal beverage cans (Figure 2). The top three persist throughout recent years (cigarette butts, rope and straws), however, in 2004 the number of balloons found were slightly less than metal beverage cans (Figure 3). In 2005 both balloons and metal beverage cans moved out of the top five and were replaced by plastic bags < 1 m and plastic beverage bottles (Figure 4). The trends over time for six of the most frequent items found are displayed in Figure 5(a-f). As stated previously, the data are normalized by the number of volunteers for each cleanup to facilitate comparison over time. Cigarette butts appear to have seasonal variability. Balloons and rope appear to have slightly decreasing trends, while beverage containers (both metal and plastic) are relatively consistent. Plastic bags less than 1 m in size may have a slightly increasing trend.

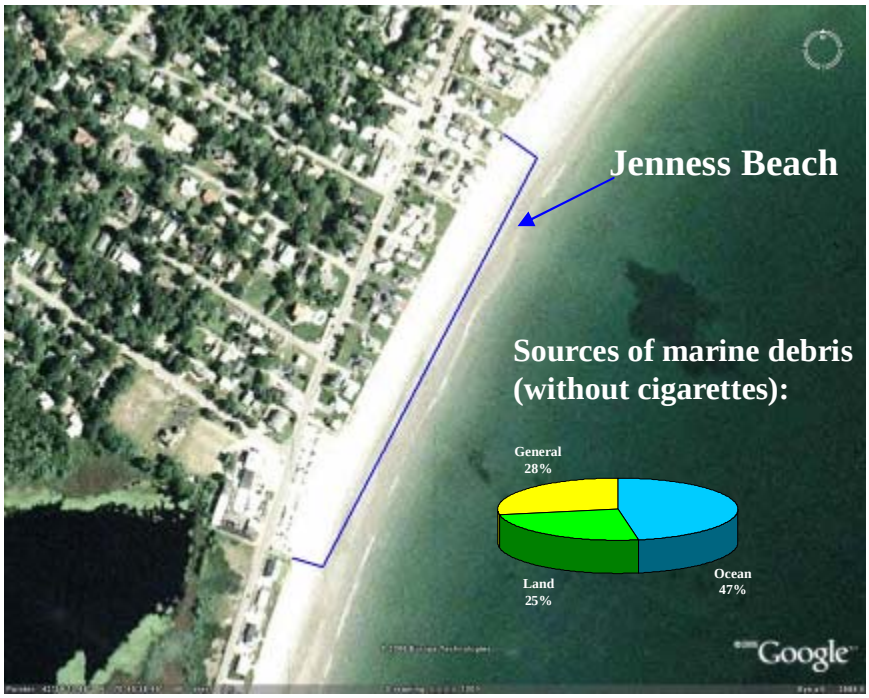


Figure 1: Jenness Beach, NH and Sources of Marine Debris Collected (2002 – 2006)

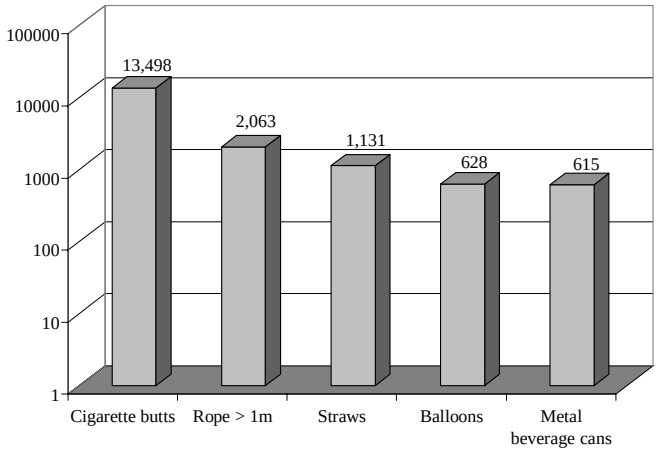


Figure 2: The Most Frequent Marine Debris Items found on Jenness Beach (2002 – 2006)

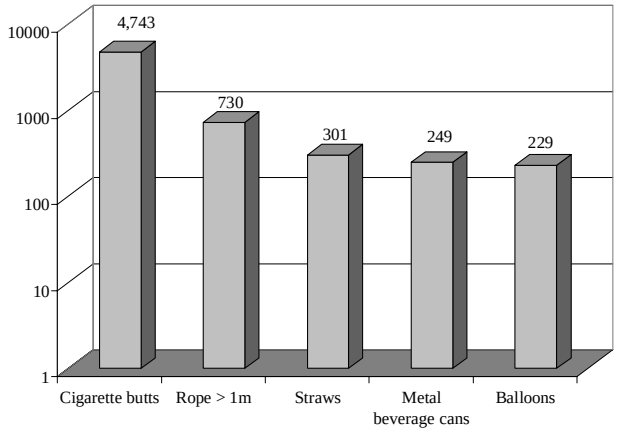


Figure 3: The Most Frequent Marine Debris Items found on Jenness Beach (2004)

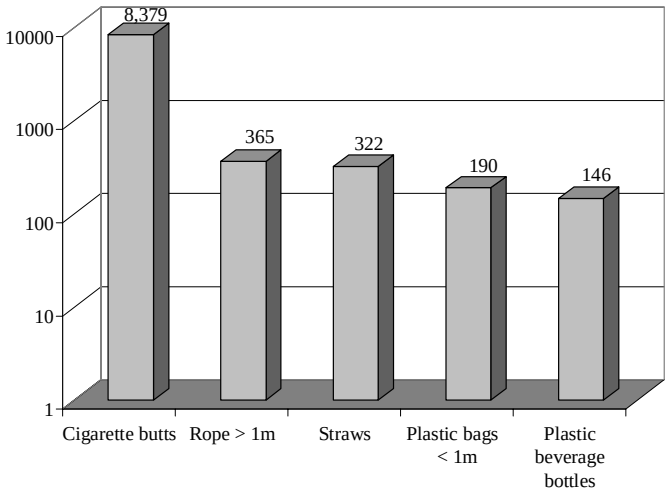


Figure 4: The Most Frequent Marine Debris Items found on Jenness Beach (2005)

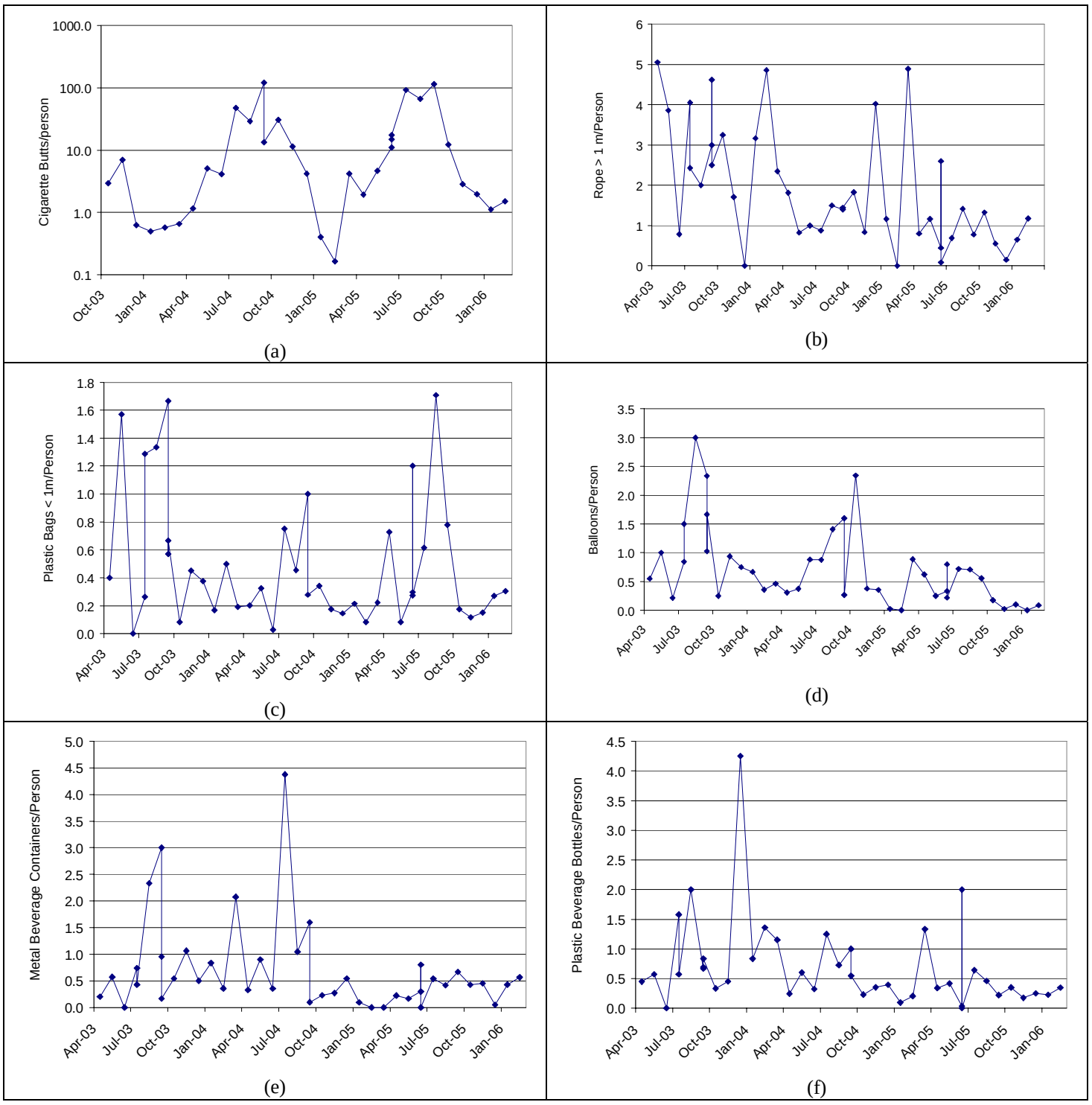


Figure 5. (a) Number of Cigarette Butts Collected per Volunteer over Time, (b) Number of Pieces of Rope > 1 m Collected per Volunteer over Time, (c) Number of Balloons Collected per Volunteer over Time, (d) Number of Metal Beverage Cans Collected per Volunteer over Time, (e) Number of Plastic Beverage Bottles Collected per Volunteer over Time, (f) Number of Plastic Bags < 1m Collected per Volunteer over Time

III. Personal Digital Assistants (PDAs) for Data Collection

PDAs with integrated GPS can be used for collecting marine pollution information to bypass the paper-to-computer transfer of data. A PDA increases data collection, and transfer efficiency and accuracy (e.g., faster data download with no entry or interpretation errors). This system not only allows for the quantity and type of marine debris to be digitally logged, but also a longitude and latitude position for each piece of debris. These data can then be used in a GIS to create maps of the coastline with the location and type of debris visually displayed on aerial photography of the area. This technology could also be transferred to other applications of marine pollution monitoring, such as shoreline assessments following oil spills. The use of PDAs for this project was initiated through an effort to integrate assessment of marine debris and shoreline oiling conditions. Ideally, the PDA-GPS system should be capable of collecting robust data sets using different levels of users (e.g., volunteers, emergency responders, and researchers).

In order to test the use of PDAs for data collection, hardware and software options were evaluated. Available software needed to be compatible with a PDA and PC database system (e.g., Microsoft Access or Excel). A prototype marine debris collection form was developed and designed. Then, the PDA system and methodology were tested and the usability evaluated. These steps are described in this section. Factors that were considered for the choice of PDA to test for this research were price, future/present users of the PDA, GPS capability, operational system, memory/other features and consumer reviews. In future applications, these devices will be used by a wide variety of persons with varying technological knowledge, so user friendliness was important. Several PDA manufacturers models were analyzed in the summer of 2006 based upon the above factors. The Garmin iQue M5 and M3 were chosen because they had integrated GPS, yet still seemed to have typical PDA user friendliness. A few months after purchasing these devices Garmin discontinued their production. Any PDA with GPS capability can work for data collection; however it is ideal to have a durable, simple to use, and accurate device.

A major factor of user friendly devices is not only for the device to work properly but to also have a simple program for data collection. Since Microsoft does not make a pocket Access program, a third party forms program was needed. Pendragon Forms software was chosen for this research because it was simple, inexpensive, and could be used to create personalized forms. The software exports collected data to Excel or Access databases. After initial form development, is was apparent that to be useful to volunteers collecting marine debris as their primary mission, the form had to fit on one screen, be easy to fill out, and react quickly to inputs. Therefore, a new form was designed with the most common debris items placed at the top of the form as check boxes. Other items remained as a look-up list or could be typed in. To obtain GPS coordinates, the coordinates must be "fixed" before the data from the form is stored. Therefore, filling out the form could take as little as two taps on the screen with the stylus and a final tap to store the data (which also clears the form for the next entry). Figure 6 provides a photo of the form developed as displayed on the PDA.

The PDA was used extensively in the summer of 2007 for dynamic marine debris monitoring and mapping. Three NH sites were chosen for weekly monitoring of changes in marine debris sources. Two sites were located on the Great Bay and were rarely visited by people (debris source is the ocean). The third site was Foss Beach, which is regularly visited by residents, but not heavily visited by tourists. None of the three monitoring sites were treated with volunteer cleanup remedies during this sampling period. A trained research assistant visited the beaches weekly noting day, time, tide, weather and logging all debris found with the PDA. This new form of data collection allowed the researchers to track debris with a higher frequency than is typically possible. Figure 7a-d shows data collected from Foss Beach and depicts how the distribution of marine debris changes over the six week sampling period

Although the PDAs as outlined above have worked well for research purposes, the goal is to eventually have volunteers utilize PDAs during cleanups; however, further refinement is needed before this occurs. Hardware and software issues presented unexpected challenges. For example, the Garmin PDAs do not have a real or virtual communication port for the GPS, so only the older versions of Pendragon work. Therefore, it is highly recommended that the hardware and software manufacturer be contacted for compatibility before purchasing either hardware of software. Pendragon technical assistance has helped to solve the few software problems encountered.

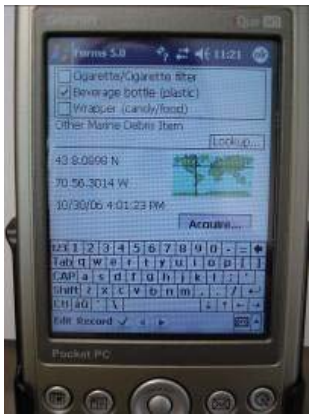


Figure 6. Form for Marine Debris Collection developed for PDA

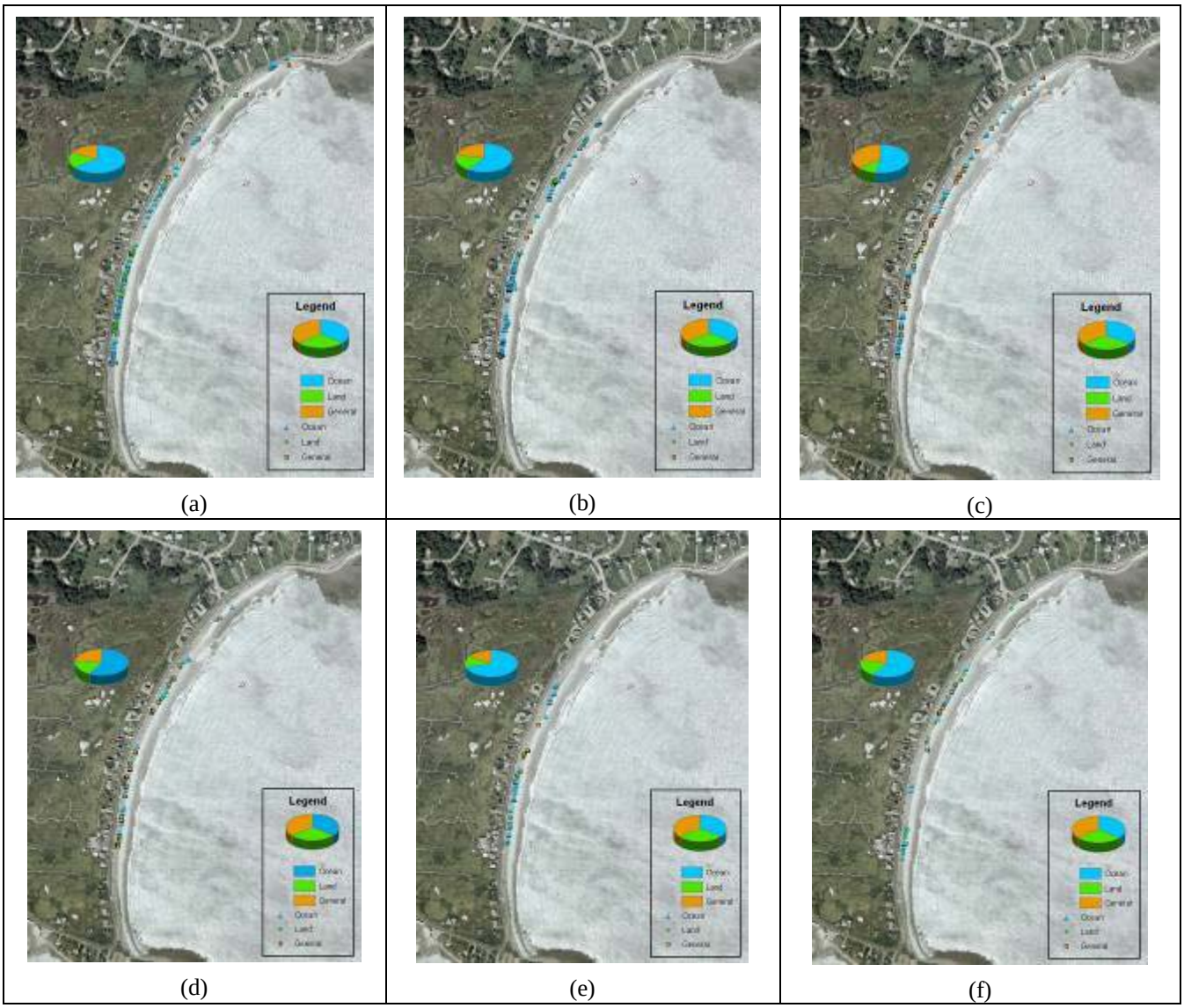


Figure 7. Dynamic Marine Debris Monitoring and Mapping at Foss Beach, NH (a) June 14, 2007; (b) June 21, 2007; (c) June 27, 2007; (d) July 6, 2007; (e) July 13, 2007; (f) July 19, 2007

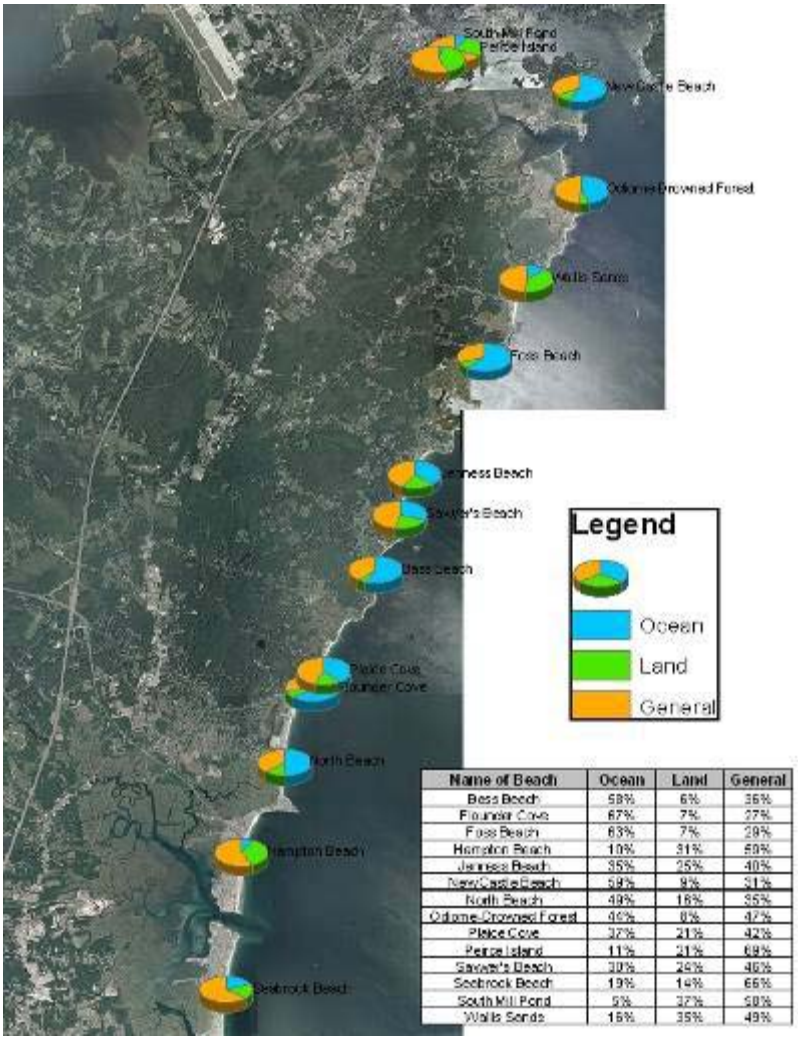
IV. Geographic information system (GIS) analysis

Marine debris composition (e.g., land-based, ocean-based) was mapped in Geographic Information Systems (GIS) along with potential influencing factors. Besides mapping the marine debris quantity and composition per collection site, the powerful component to GIS is that any potential influencing data available can be tied to all of these locations. The eventual full integration of all available data will allow the researchers to examine trends and correlations in marine debris data with myriad potential influences.

A basemap was created for the coast of New Hampshire, using aerial photography as well as data layers from multiple governmental agencies. Urban areas, key destinations, land cover, land use, stormwater outfalls, fishing locations, estuarine areas, and other data were also mapped on the coast. These data can be used in conjunction with the data collected by beach cleanups to better delineate possible sources of marine debris affecting specific beaches. GIS allows data to be used in a spatial environment rather than just being stored on a spreadsheet. For the purpose of this research and analysis, distance to the above factors from a beach will be used as a basis for determining the effect on the prevalence of the type of marine debris.

A summary of the sources of marine debris (as was conducted in Section II, with cigarette butts removed) for each beach was mapped for all the beaches monitored in 2006 (Figure 8). Ocean-based debris dominates (greater than 50%) the impact for four out of fourteen beaches. This is unique in that typically land-based debris is greater; however, New Hampshire has a relatively large fishing industry, with portions of derelict crab pots and lobster traps, as well as rope, representing a major source. Land-based debris represented less than 50% of the total debris for all of the beaches sampled. However, debris classified as "general debris" may tend to be land-based for beaches visited by people and tourists; however, this hypothesis may be further tested by research such as this. For example, Hampton Beach, the most tourist-visited beach in New Hampshire, 90% of its collected debris is from both land and general sources (this is without cigarette butts). When categorized together, land and general sources of debris represent greater than 50% at nine of the beaches sampled.

The pie charts presented in Figure 8 and the data they symbolize can be used in conjunction with other GIS layers, such as locations classified as "urban areas" of the coast, to create a map and conduct a spatial analysis (Figure 9). According to the GIS analysis conducted for this research, 50% (seven) of the fourteen beaches intersect or are within 0.4 km (¼ mile) of an urban area. An urban area near a beach provides more opportunity for people residing in this area to visit the beach. Additionally, an urban area provides infrastructure, such that a higher number of tourists may visit this area because it is accessible and provides options for activities, restaurants and shopping. Only one of the beaches (Flounder Cove) near an urban area has greater than 50% ocean-based debris. The other six beaches have a greater percentage of land- and general-based debris.



Name of Beach	Ocean	Land	General
Bass Beach	58%	6%	36%
Flounder Cove	67%	7%	27%
Foss Beach	83%	7%	29%
Hampton Beach	10%	31%	59%
Jenness Beach	35%	25%	40%
New Castle Beach	58%	9%	31%
North Beach	49%	16%	35%
Odiorne Drowned Forest	46%	8%	47%
Pleice Cove	37%	21%	42%
Pierce Island	11%	21%	68%
Seavey's Beach	30%	24%	46%
Seabrook Beach	19%	14%	66%
South Mill Pond	5%	37%	58%
Wallis Sands	16%	35%	49%

Figure 8. NH Beach Monitoring Locations and Sources of Marine Debris Collected at each Beach in 2006

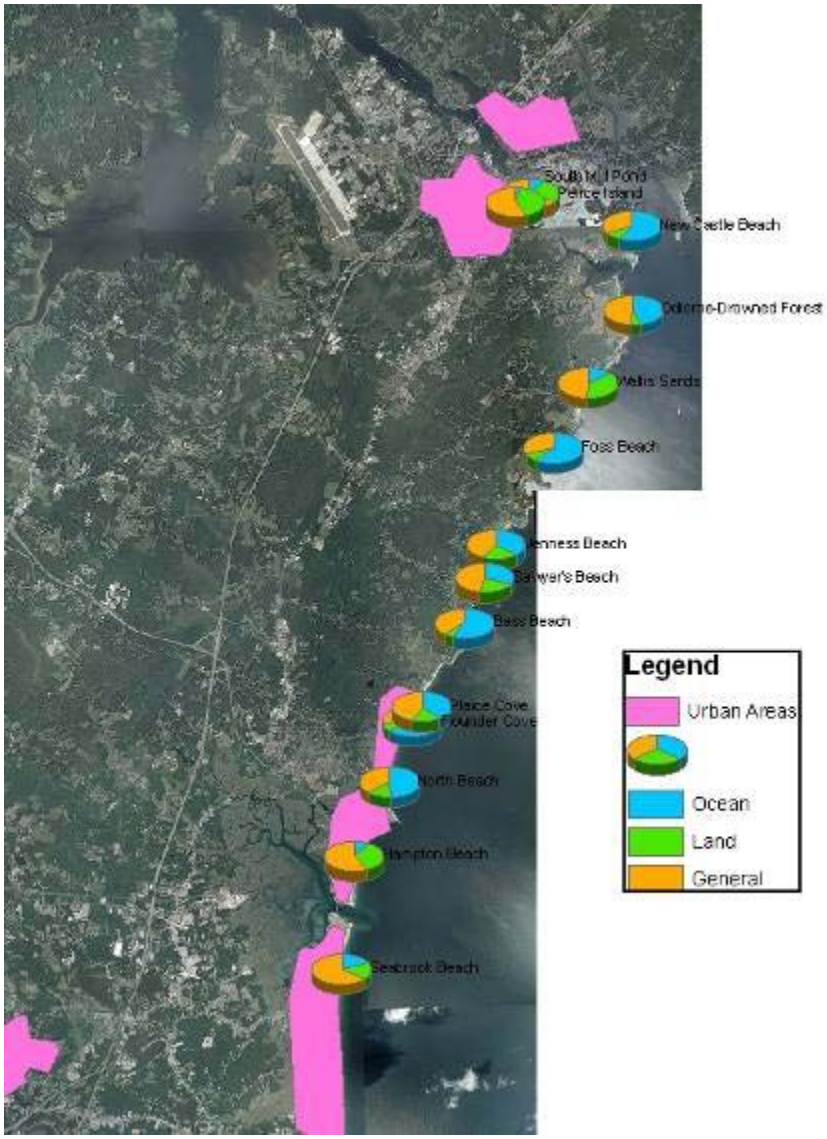


Figure 8. NH Beach Monitoring Locations, Sources of Marine Debris Collected (2006) and urban areas

V. MITIGATION STRATEGIES AND FUTURE RESEARCH

Since this research commenced, the State of New Hampshire has placed cigarette butt disposal containers at Hampton Beach. Future beach cleanup data will determine if these had an impact on debris quantities and characterization. Other potential mitigation strategies include more accessible trash receptacles (NH is a carry-in/carry-out state for trash on beaches), offering fishing gear disposal receptacles (e.g., monofilament line recycling centers) and restricting activities, such as smoking, on beaches (e.g., beaches near San Diego). The maps produced for this research provide visual representation for decision-making and education and can subsequently be used for scientific analysis as well as public awareness of marine pollution. More public awareness and education may help to mitigate this pervasive marine pollution problem. Additionally, because the amount of ocean-based debris found on the NH Seacoast is greater than land-based debris for the majority of beaches, a new outreach program targeting commercial and recreational fisherman is being implemented in a partnership with NH Sea Grant.

A comprehensive report is under development that will include the data summary from each of the fourteen beaches monitored through 2006 by BOS. The GIS maps assist in determining the distribution of the three sources of debris as well as illustrating trends in marine pollution and the data presented here is the initial GIS analysis conducted at UNH. Continued analysis will occur including a spatial analysis of the debris mapped on a weekly basis (Section III) that will quantify changes in debris patterns each week. Other data sets (e.g., including fishing areas) will be mapped with the beach locations and pie charts shown in Section IV. Even though the NH Seacoast has less than 20 miles of coastline, the marine debris issue is of significance and new technologies

that encompass monitoring and mapping play a key role in evaluating impacts of debris, as well as mitigation strategies that can then be transferred to other locations throughout the world.

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